Australian Government
Department of Defence
Defence Science and
Technology Organisation

Investigating the Quality of Service of Current and Future Tactical Information Exchanges - Net Warrior

Arthur Filippidis, Mark Eldridge, Maurizio Gencarelli

Air Operations Division
Defence Science and Technology Organisation

DSTO-TR-2429

ABSTRACT

A series of Net Warrior exercises is planned to build, demonstrate and enhance Australian Defence Force Network Centric Warfare (NCW) interoperability. Under the auspices of Task CIO 07/042 and as part of a student vactional work experience project this report describes the use and functionality of the Quality of Service (QoS) software tool developed by Adelaide University under a DSTO contract funded by the AEW&C Project. It realistically characterises the radio communication environment in the tactical battlespace, and with the use of a Rosetta Gateway can be used in future Net Warrior exercises involving Tactical Digital Information Links (TADIL) between nodes (ie. mission system test-beds) within DSTO. Using Rosetta together with the QoS software the report also analizes a possible future scenario using current and future data links comparing the tranfer rates over time and hop counts between point to point and networked connections between two nodes. In this case the report shows an improvement in the quality of service and reliability in a possible future Global Information Grid Environment where nodes are ideally networked.

RELEASE LIMITATION

Approved for public release

Published by

Air Operations Division
DSTO Defence Science and Technology Organisation
506 Lorimer St
Fishermans Bend, Victoria 3207 Australia

Telephone: (03) 9626 7000
Fax: (03) 9626 7999

AR-014-793
May 2010

APPROVED FOR PUBLIC RELEASE

Investigating the Quality of Service of Current and Future Tactical Information Exchanges - Net Warrior

Executive Summary

In response to the committed expenditure by the Australian Defence Force (ADF) to Tactical Digital Information Link (TADIL) acquisitions, the Defence Science & Technology Organisation (DSTO) is endeavouring to focus its support in the area of Tactical Information Exchanges. The ADF has also recently experienced significant data link interoperability and integration problems, some ongoing, in acquiring and operating a number of its airborne mission and maritime combat systems. In response to this the Mission System Research Centre (MSRC) is being developed as part of the AOD Aerospace Battle Lab Capabilities. A series of Net Warrior exercises is planned to build, demonstrate and enhance ADF Network Centric Warfare (NCW) interoperability. The Airborne Systems Connectivity Environment Laboratory (ASCEL) in AOD contains several TADIL hardware and software systems. Tactical data links are used to exchange and share battle-space situational awareness information and are one of the key areas of interest in Network Centric Warfare research. Under the auspices of the Tactical Information Exchange task CIO 07/042, and as part of a vacational student project this report explores the use of the Quality of Service (QoS) software tool recently developed by Adelaide University to realistically characterise the radio communication environment in the tactical battlespace. The report describes one possible future scenario using current and future data links comparing the tranfer rates over time and hop counts between point to point and networked connections between two nodes. Showing in this case an improvement in the quality of service and reliability in a possible future Global Information Grid Environment where nodes are interoperating in a networked environment.

Authors

Dr Arthur Filippidis
Air Operations Division

Arthur Filippidis obtained his B. Eng. in Electronic Engineering from the University of South Australia. Prior to joining the DSTO in 1985, he worked for Tracker Communications in South Australia, and the Naval Engineering Design section of the Department of Defence in Canberra. While working as a profesional officer with DSTO, he received a M. Eng. Sc. degree from the University of Adelaide in 1994, and a Ph.D. degree from the University of South Australia in 1999 in the areas of data fusion, artificial intelligence and automatic target detection. Whilst at DSTO he has authored/co-authored over 90 refereed conferences, journals, book chapters and defence technical reports. As an Adjuct Senior Research Fellow he has participated in the research programs of the Knowledge Based Intelligent Engineering Systems Research Centre, University of South Australia. In early 2002 he joined the Air Operations Division, and has mainly worked in the area of Tactical Communications. Currently he is task manager of the Air Plaform Connectivity Task, CIO 07/042, in Airborne Mission Systems Branch and has developed the Airborne Systems Connectivity Environment Laboratory to conduct further research in this area.

Mark Eldridge
DSTO

Mark Eldridge is currently studying a double degree in Aerospace Engineering and Computer Science at the University of Adelaide. During 2008 he was accepted into the DSTO Summer Vacation Scolarship program, and as a result undertook a research project in the Air Operations Division at DSTO Edinburgh over the 2008/09 university holiday period, after which he will complete his final year of study.

Maurizio Gencarelli
Air Operations Division

Maurizio Gencarelli obtained his B. Eng. in Electronic Engineering from the University of South Australia in 1987. Prior to joining the DSTO in 2006, he worked for the Aircraft Research&Development Unit (ARDU) of the Aerospace Operations Support Group, Royal Australian Air Force in Edinburgh Adelaide. Whilst at ARDU he worked as an Avionics Design Engineer on the design and development of electronic systems in support of Operational Flight Test activities on miltary aircraft. Currently, he is working for the Airborne Mission Systems Branch of the Air Operations Division and has been actively involved in the area of Tactical Data Links and Reconfigurable Computing.

Contents

1. INTRODUCTION 1

2. AIRBORNE SYSTEMS CONNECTIVITY ENVIRONMENT LABORATORY 2

3. FUTURE TACTICAL INFORMATION EXCHANGES 4
   3.1 TIE Technology Overview 4
   3.2 Joint Tactical Radio System (JTRS) 4
   3.3 Tactical Target Networking Technology (TTNT) 4
   3.4 Common Data Link (CDL) 5
   3.5 Link-22 6

4. FUNCTIONALITY OF THE QUALITY OF THE SERVICE SOFTWARE USING ROSETTA 7
   4.1 Introduction 7
   4.2 Scenario Creation 8
   4.3 Geographical Information Systems 9
   4.4 The QoS Software 9
   4.5 Results and Analysis 10
   4.6 Networking 12

5. SUMMARY AND CONCLUSION 15

6. REFERENCES 16

1. Introduction

A series of Net Warrior exercises is planned to build, demonstrate and enhance ADF Network Centric Warfare (NCW) interoperability. Through experimentation these exercises are aimed at addressing new and evolving NCW and mission system techniques and technologies to enhance joint war fighting capabilities. The Airborne Systems Connectivity Environment Laboratory (ASCEL) in the DSTO Air Operations Division (AOD) contains several Tactical Data Link (TDL) hardware and software systems, such as the Rosetta Gateway which can translate, create and display various TDLs. Tactical data links are used to exchange and share battle-space situational awareness information and are one of the key areas of interest in Network Centric Warfare research. (Note this report describes only one of several planned activities within the Net Warrior program.)

Under the auspices of the DSTO task 07/042 the Centre for Defence Communications & Information Networking (CDCIN) has developed a software tool for the ASCEL that realistically characterises the radio communication environment in the tactical battlespace. The software tool displays the quality of service between any platform or testbed/ node, and can add more realism in a Net Warrior exercise. The Quality of Service (QoS) software interfaces to a Rosetta lap-top in the ASCEL to be able to use the nodes/platforms (i.e., AEW&C Mission System Testbed) in a future Net Warrior simulation exercise. The software will support current link technologies such as Link-11, Link-16 and VMF. It also includes future systems such as Link-22 (using the typical HF & UHF frequency bands) and technologies that support IPV-6 such as Common Data Links (CDL) (using the typical up & down link frequencies & the ability to change these if required), Tactical Targeting Network Technology (TTNT) and Wide-band Network Waveforms (WNW). The QoS software will be integrated with a Geographic Information System (GIS) (Arc-View by ESRI corporation) which will enable analysts to add geographic and topographic information relevant to the scenario, as well as RF jamming effects.

The QoS software may in the future complement the other numerous experiments being conducted or planned as part of Net Warrior such as the concept of the Synthetic Range. This is where live assets are instrumented to allow their interoperability with virtual and constructive systems in the same virtual synthetic environment. Such synthetic range environments are sometimes referred to as LVC (Live, Virtual, and Constructive) environments. To increase the fidelity of future LVC and other experiments, being mainly conducted across Ethernet, the QoS software was developed and interfaced to TDL equipment in the ASCEL using the Rosetta Gateway.

The objective of Net Warrior [1] is to provide DSTO with a NCW research capability. In summary this report:

1. Briefly discusses the functionality of the QoS software developed by CDCIN under the direction of DSTO to realistically characterise the radio communication environment in the tactical battle space and provide increased fidelity to experimentation in Net Warrior exercises using current and future Tactical Information Exchanges (TIEs). Future tactical communication technologies such as the Internet Protocol based transmission approaches may be investigated with other participating nodes in future Net Warrior experiments. Information derived from these experiments will contribute to building our knowledge of how ADF platforms fit into the future Global Information Grid with coalition forces.
2. As part of an undergraduate student project, explores and analyses networking and quality of service characteristics of current and future TIEs between simulated nodes in different scenarios and GIS's (i.e. varying terrains, and elevations).

2. Airborne Systems Connectivity Environment Laboratory

The ASCEL in the Air Operations Division (AOD) of DSTO contains several Tactical Digital Information Link (TADIL) Commercial-Off-The-Shelf (COTS) systems. These COTS systems include the Northrop Grumman Dual Link Simulator with Extended Capability (DLS-EC), Common Connectivity Device (CCD), Gateway Manager and the Rockwell Collins Rosetta Link Translator Gateway. They are used for connecting local and external simulators together and conducting exercises which aim to comply with the general principles outlined for the future Global Information Grid (GIG) [2].

The Rosetta system [1] is supplied with a Joint Tactical Information Display System (JTIDS) Moving Map Tactical Information Display System (JMMTIDS) application. The JMMTIDS can function as a moving map display and can also display data link data streams on top of any Map or Imagery product.

The TDL Wide Area Network (WAN) linking all ADF simulators and Regional Operational Centres has being rolled out by the Australian Defence Force TDL Authority (ADFTA). A recently installed DSTO ADFTA TDL WAN node connection, located in the ASCEL, will allow the Net Warrior participants described in Figure 1 to interoperate with external ADF simulators, real platforms (in non operational roles) and monitor future coalition exercises in the ASCEL.

The ASCEL also incorporates the DSTO developed Air Defence Ground Environment Simulator (ADGESIM) [3] which is a high fidelity system used by the RAAF for training Air Defence Controllers using their operational systems. Figure 1 displays a possible short term Net Warrior network using the ADGESIM software, together with the DLS-EC, Rosetta and CCD in the ASCEL interoperating using the DIS and J-series networks with the other nodes (i.e. the Intelligence Surveillance & Reconnaissance Division (ISRD) Developmental Regional Operation Centre (DROC) and the Maritime Operations Division (MOD) Virtual Ship). Although not shown, the QoS software resides together with the Rosetta software (refer to Figure 1) on a personal computer which is connected to the DLS-EC by 1553, enabling node information to be easily sent to QoS for processing and display.

ADGESIM in this initial network consists of a Distributed Interactive Simulation (DIS) radio, Qantas airline scheduler (which can create way points and schedules), world viewer (showing world entities), After Action Review (AAR) data logger and the Soliypsys Multi-source Correlator Tracker (MSCT) and Tactical Display Framework (TDF). The Australian Air Traffic System (TAATS) and Jindalee Operational Radar Network (JORN) Over The Horizon (OTH) simulators, developed by Permian, monitors the virtual environment on the DIS network and produces J-series messages.

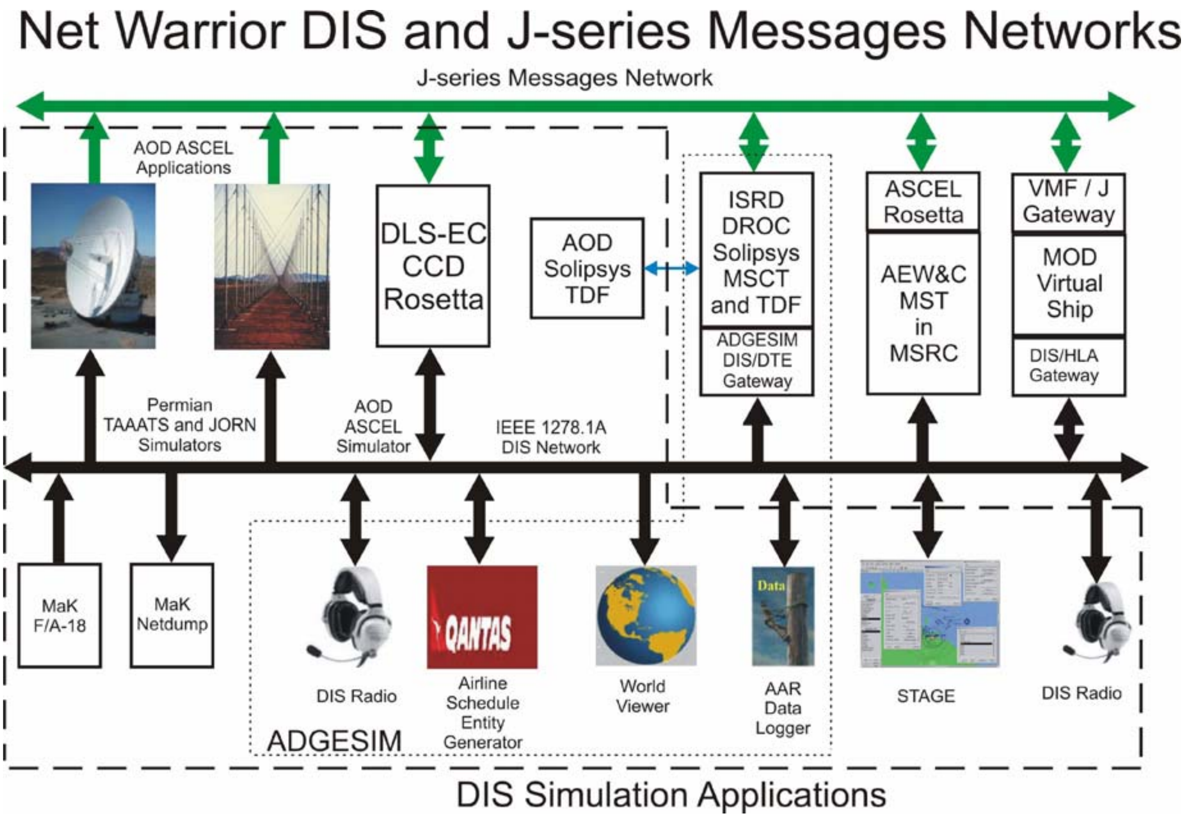


Figure 1: Displays a possible Net Warrior DIS and J-series short term architecture using the ADGESIM, DLS-EC and CCD in the ASCEL together with several of the external nodes located in the Intelligence Surveillance and Reconnaissance Division and the Maritime Operations Division [1]

3. Future Tactical Information Exchanges

3.1 TIE Technology Overview

Development of new tactical communication technologies primarily aims at providing war fighters with greater electronic warfare capabilities as well as allowing existing tactical communication equipment such as Link-16 to coexist. Recent developments in this field include the Joint Tactical Radio System (JTRS), TTNT, WNW and CDL. These technologies make use of Internet Protocol (IP), which has been the backbone of the computer internet world, to support connectivity from the tactical environment into the Global Information Grid (GIG). TTNT is of particular importance to the Australian Defence Force since the Joint Strike Fighter F35 may be equipped with this technology.

Future Net Warrior experiments may look into the interoperability and connectivity issues of introducing new tactical communication technologies between numerous nodes interoperating with current data links.

3.2 Joint Tactical Radio System (JTRS)

JTRS is the next generation radio system for the defence force addressing the inability of different types of radio to work together and is an important component of the information infrastructure supporting the GIG. JTRS belongs to a class of software-defined radio system (SDR), which enables one radio to communicate with several radio networks.

Components making up JTRS include proprietary software waveforms, generic radio hardware and an operating system. The hardware converts analog radio signals to digital data. The software processes the digital data and controls the frequency, modulation, bandwidth, security functions and waveform requirements [4]. The software that runs on the radio microprocessor must conform to the Software Communications Architecture (SCA) which is published and maintained by the Joint Program Executive Office (JPEO) for JTRS.

JTRS is predicted to significantly reduce Radio Frequency (RF) management and maintenance due to the flexibility of the system, which allows new functionality to be incorporated without replacing or upgrading the radio hardware [4, 5, 6]. Reconfiguring the radio receivers can simply be achieved over the air. JPEO defines the JTRS waveform implementation which consists of a Waveform Application Code, Radio Set Devices and Radio System Applications.

JTRS is a critical component of Network Centric Warfare infrastructure since it connects the tactical edge to the GIG. However, there are still challenges in the development of JTRS. Unlike the hardwired reliable networks, RF based networks suffer from interference, limited bandwidth and interruption due to the mobility of the nodes [7].

3.3 Tactical Target Networking Technology (TTNT)

TTNT is designed to address the four areas of deficiencies in the current tactical data link systems which include slow retargeting, insufficient bandwidth with high latency, tedious network re-planning and incompatibilities with other tactical communication systems [8].

TTNT is a high speed data link airborne network designed to detect, track and prosecute time-critical targets. TTNT provides near instantaneous connectivity between manned and unmanned airborne platforms and ground stations with a tested latency of less than 2 milliseconds. The technology uses the standard IP for communication between platforms. TTNT combines three moving sensor platforms to triangulate and find the precise geolocation of the enemy target. If the target happens to relocate, TTNT is able to update the target with high accuracy and prosecute the target [8].

The technology is being developed by Rockwell Collins. As reported in [8], the data transmission rate for an airborne platform fitted with TTNT is 2 Mbps while simultaneously receiving at 10 Mbps within a 100 nautical mile radius of the battle-space. The high throughput enhances the situation awareness and has the potential to provide live video to control headquarters. A key feature of TTNT is the automatic ad hoc networking. Forming a net or performing a net-entry takes less than 5 seconds, which eliminates the time-consuming task of network re-planning, a major issue for the current tactical data link.

Data link transceivers for TTNT are being developed to be inserted into existing Link-16 terminal such as the Multifunction Information Distribution System Low Volume Terminal (MIDS LVT) to create a new hybrid terminal which is called MIDS JTRS [9]. Both Link-16 and TTNT waveforms will be loaded as software applications on JTRS radios.

3.4 Common Data Link (CDL)

The Common Data Link (CDL) system as defined by [10] is a family of full duplex, jam resistant, point-to-point microwave communication links used in the transmission of images and signals intelligence to support the battle field. CDL does not contain pre-defined messages and therefore is not a TADIL family. The CDL family of system includes Tactical Common Data Link (TCDL), Interoperable Data Link (IDL), Miniature Modular Interoperable Data Link (MIDL), Modular Interoperable Surface Terminal (MIST) and Dual Data Link (DDL). CDL provides wideband line of sight (LOS) communication services for platforms and sensor payloads to support a wide range of Intelligence, Surveillance and Reconnaissance (ISR) applications. CDL supports point-to-point and one-to-many but does not support many-to-one communication. Figure 2 depicts a scenario in which CDL may be used between various ground stations, surface and air platforms.

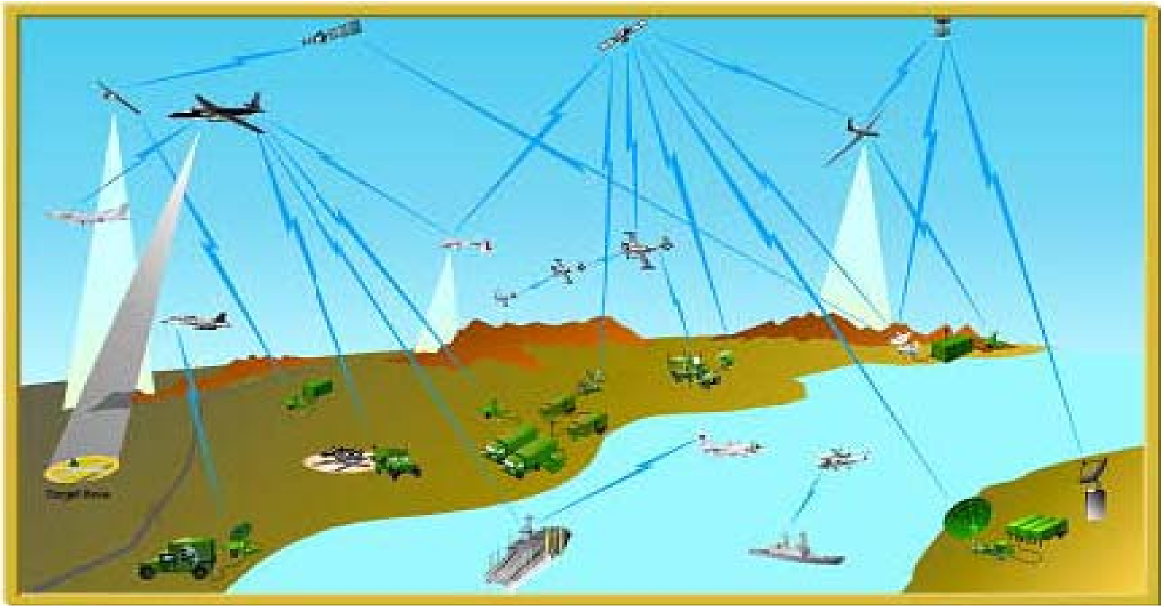


Figure 2: Communication scenario for CDL between ground stations, surface and air platforms [11]

The standard CDL has evolved over the past four decades and was standardised in 1988. As reported in [11], there are approximately 450 CDL-based systems in operation or in development in the US defence force.

CDL can be used to carry large amounts of data over an RF link to service tactical messages, voice, images, file transfers and limited video channel. CDL is also known as the IP “pipes” to carry ISR information at traditional data rates of 200 kbps for forward link and at 10.71 Mbps, 137 Mbps and 274 Mbps for return link. The current CDL family can operate at several data rates and use various types of waveforms.

An inherent limitation of the CDL system is that the combined antenna gain must be high enough for the system to operate over the required ranges and data rates. Practically, this requirement translates to large antenna dimensions for a ground system and a smaller antenna for an airborne system. For air-to-air data link applications, antenna dimensions are smaller, the antenna gain is lower therefore ranges and data rates would be lower. Weather factors such as heavy rain can severely deteriorate the links [12].

As demand for CDL bandwidth continues to grow, higher frequency bands would be required to cater for the demand increases. In the NCW context, CDL will continue to evolve and play an important role in the communication architecture of the GIG.

3.5 Link-22

The NATO Improved Link Eleven (NILE) programme commenced in 1990 to replace Link-11 with a system (Link-22) working in the same frequency bands, to complement Link-16, improve electronic protection measures and allied interoperability [13].

Link-22 is a member of the "J-Series family", hence has a commonality with Link-16 using modified J-Series messages. However to create messages unique to Link-22 requirements a further set of messages, known as F- Series messages, has been developed.

The key features of Link-22 operations are:

- Nodeless Time Division Multiple Access (TDMA), which continues to operate without Network Managers
- Enhanced connectivity, via automatic routing and relays
- Interrupt slots which report high priority messages
- On-going capacity reallocation via dynamic TDMA
- Automated optimisation of time slot allocations
- Automated link establishment and re-configuration
- Automated late entry.

Link-22 operates in either the HF or UHF frequency bands. In each of these frequency bands the system can operate on a single frequency or a pseudo-random frequency hopping mode. In frequency hopping mode a hop set defines a channel.

4. Functionality of the Quality of the Service Software Using Rosetta

4.1 Introduction

The QoS software package models the propagation of current and future TIEs. This software can hook into a tactical scenario through an interface into a Rosetta database. The Rosetta database itself can be populated with message data in a number of ways, for example through the Joint Moving Map Tactical Information Display System (JMMTIDS) software [1,3] module or through a 1553 Military data bus. A scenario with tactical data messages being transmitted between platforms is read by the QoS software to determine the current tactical situation. This information includes the location, altitude and path of transmitting platform and the other platforms in this scenario. This information is updated in the QoS simulator as the simulated environment changes.

The QoS Simulator can then determine the expected quality of service of the tactical links. The simulator uses the COTS Arc-View GIS software module to incorporate relevant geographical data into the QoS model. A radio propagation module which incorporates both the land elevation data and a land use model has been developed to approximate the radio attenuation of any radio signals in the tactical environment. (Note a land usage database describes the use of land at particular geographic location. The different land usages - urban, forest, ocean etc - affect the radio propagation. The land use model takes these affects into consideration when calculating the radio signal attenuation.) The radio attenuation of point to point radio communication links determines the data rate capabilities of these point to point links. These rates depend on the specific technology being deployed. There is also a simple feed back mechanism in which if there is a choice of technologies – for example Link 22 may use a HF or a UHF frequency – the technology which leads to the higher data rate is chosen. Whereas the Rosetta application can only store current tactical link messages such as Link-16 and Link-22, the QoS simulator can also use a model for TTNT, WNW, and TCDL to demonstrate the higher capability of these new technologies. This enables a comparison of these technologies to be undertaken.

4.2 Scenario Creation

The QoS simulation software relies upon a tactical scenario described by a Rosetta database. The JMMTIDS software and Scenario Generator Tool (SGT) were used to create several basic tactical scenarios, in order to evaluate the performance of different Tactical Data Links (TDLs) using the QoS software.

These scenarios were not created from a strict military realism perspective, but were intended to cover some basic situations involving the use of Tactical Data Links (TDLs) between military units, including air, land and sea communications, as well as both Line Of Sight (LOS) and Beyond Line of Sight (BLOS) requirements. The ability of each TDL to cope with these requirements was evaluated using the QoS software, including considerations regarding link throughput and range.

Figure 3 shows a simple scenario involving 4 aircraft (2 Fighters, 2 Command & Control) and 2 Destroyers. This scenario can be loaded into the QoS software, where the link types available to each unit can be altered. The effect each link type has on transfer rate and number of relay 'hops' (times a transmission must be routed (or received and retransmitted) in order to reach its destination) can then be analysed.

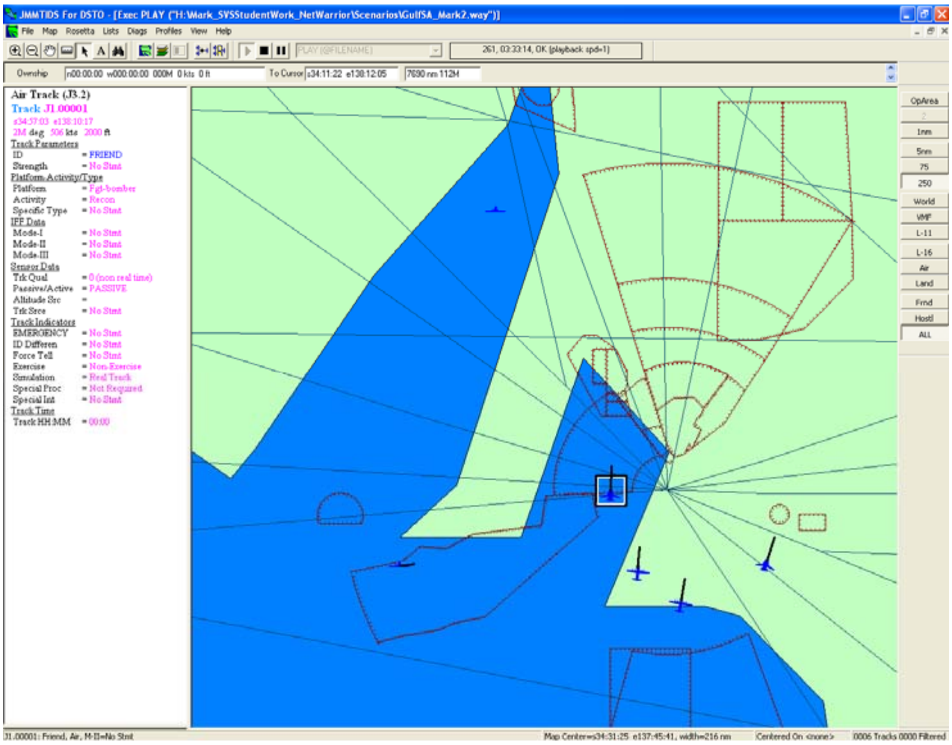


Figure 3: A simple scenario created for use with the QoS software, containing four aircraft and two naval units. Platform J1.00001 (fighter aircraft) is highlighted.

4.3 Geographical Information Systems

The QoS Software makes use of a COTS Geographical Information System (GIS) produced by ESRI called *ArcGIS*. A Geographical Information System, in a general sense, allows for information such as topography, land usage, etc, to be mapped according to geographic position - the same concept of a paper map or street directory, but much more versatile and powerful. GIS systems have gained more public recognition in recent years, with free consumer software and web applications such as Google Earth and Google Maps giving GIS software a great deal of publicity. GIS software is used in a multitude of different areas from local government to mining to defence, and is useful for many tasks since any information with a geographical component can benefit from a GIS.

The QoS software makes use of an ArcGIS map of the scenario area, which involves a layered raster map with one layer for terrain, one for elevation, and one for land usage (ocean, agricultural, forest, etc). This information is used to determine signal attenuation for each link between a pair of platforms (also taking into account the presence of any jammers), with the resulting signal strength used to determine whether or not data transfer is possible.

Elevation and land usage are not the only information which could be implemented using GIS techniques. Additional information which could be used to make simulations more accurate could include:

- Known electromagnetic (EM) interference (using position information of radio towers, mobile phone towers, etc) could be included as another layer, and used to examine any effects on platform links, including whether some link types are more susceptible to EM interference than others.
- Atmospheric data such as cloud cover could be used to examine any detrimental effects on each link. Again, it would be expected that some link types would be more susceptible to interference from cloud cover than others.

Of course, any added GIS information used would need to be taken into account by the models used by the QoS software.

4.4 The QoS Software

The software is written using the Java language, a language designed to be multi-platform – however the QoS software itself is not multi-platform, as it relies on COTS components which are currently restricted to Microsoft Windows systems.

Many enhancements have been made to the software since it was originally delivered, as the source code is owned by DSTO. These enhancements range from purely aesthetic changes (e.g. typographical errors) to modifications to the format of the output data making it easier to manipulate.

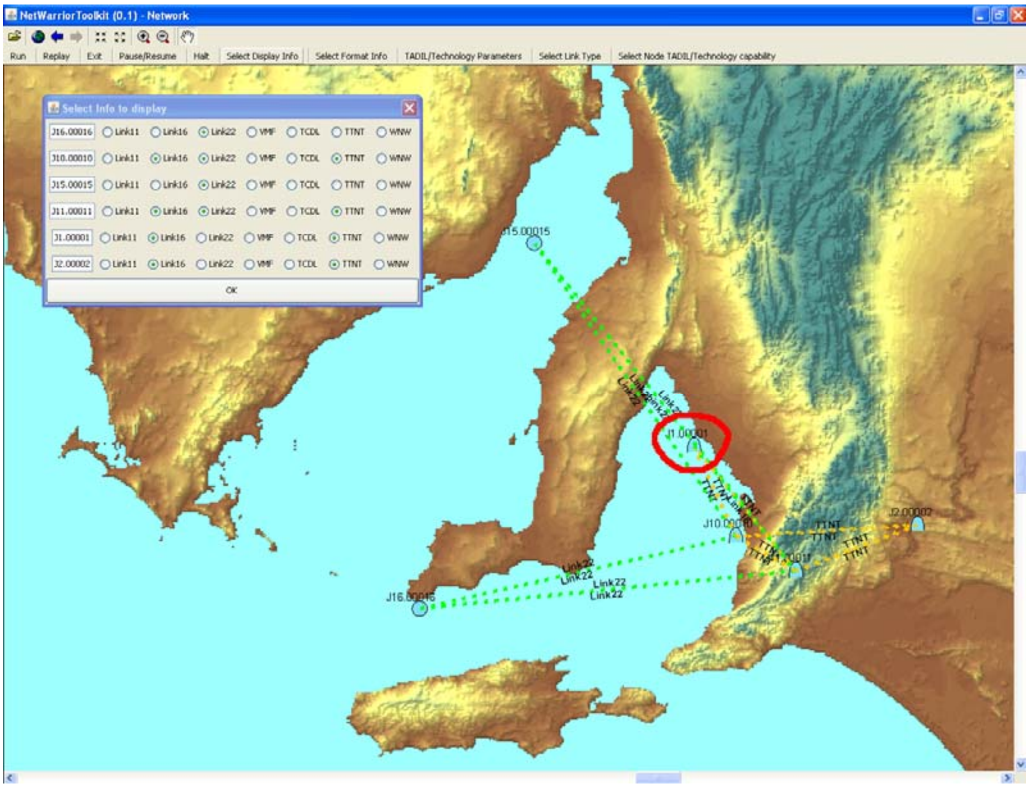


Figure 4: *The QoS Software running the scenario created using the Scenario Generator Tool. The dialog box shown onscreen is used to set link capability for each platform. Platform J1.00001 is again highlighted.*

4.5 Results and Analysis

The QoS software is able to store all data recorded during a simulation to a comma-separated values (.csv) file, which can then be manipulated using spreadsheet software such as Microsoft Excel.

Analysis involves filtering the recorded data by source and destination platform in order to create plots for each link of interest, and allow for easy comparison between different link types and point-to-point or networked operation. Some of the plots created were transmission rate over time (in bits per second, or bps) for each source / destination pair, and the number of hops required for a connection.

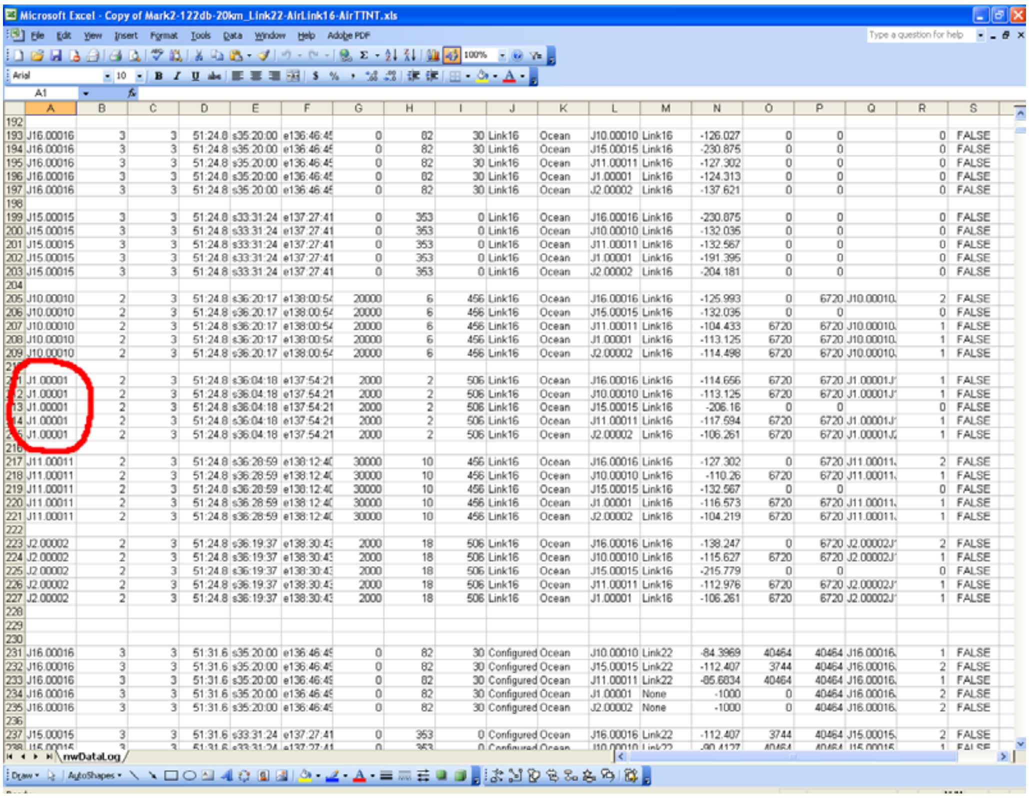


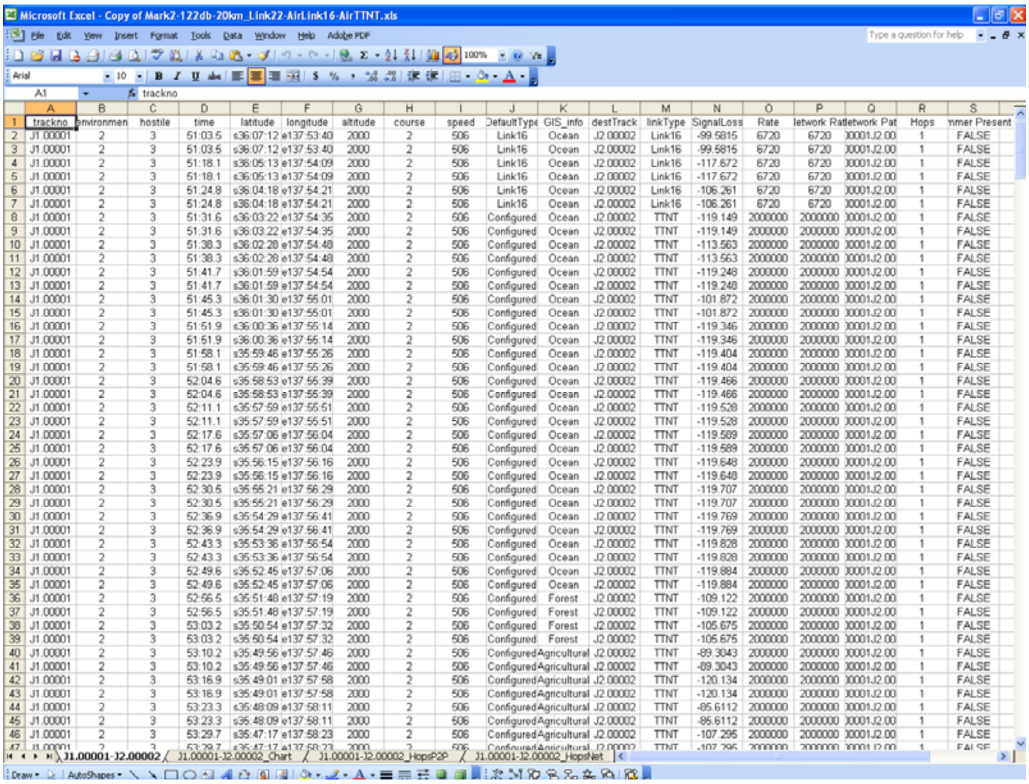
Figure 5: The log file generated by the QoS software. The highlighted area shows a time step with links from platform J1.00001 to all other platforms.

The raw output data generated by the QoS software (and also used as input data for replays) is a spreadsheet with groups of rows corresponding to a particular platform's link to every other platform at a given time step. As shown in Figure 5, column A lists the source platform, with the destination platform shown in column L. Column J shows the overall link type being currently used: Link16 is used at the beginning of the scenario (the default link) until the individual platform link capabilities can be set. Once they are set, the link is changed to 'configured', and the particular link being used for a given connection is shown in column M.

Manipulation of the data generated by the QoS software is greatly assisted through the use of Macros written for Microsoft Excel. These Macros are written using Visual Basic for applications, and can perform the following tasks:

- Process data for easier manipulation
- Filter data and generate graphs for the connection between two platforms over time
- Filter data and generate graphs for the connections between one platform and all other platforms over time

These macros generate graphs of transmission rate (in bits per second, or bps) over time, comparing the performance of direct links to that of idealised networking. Pie charts, showing the number of network hops needed for a connection as a proportion of time, are also generated.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	trackno	environmen	hostile	time	latitude	longitude	altitude	course	speed	DefaultType	GIS_info	destTrack	linkType	SignalLoss	Rate	letwork Rat	letwork Pat	Hops	nmer Present
2	J1.00001	2	3	51:03.5	s36:07:12	e137:53:40	2000	2	506	Link16	Ocean	J2.00002	Link16	-99.5815	6720	6720	)0001J2.00	1	FALSE
3	J1.00001	2	3	51:03.5	s36:07:12	e137:53:40	2000	2	506	Link16	Ocean	J2.00002	Link16	-99.5815	6720	6720	)0001J2.00	1	FALSE
4	J1.00001	2	3	51:18.1	s36:05:13	e137:54:09	2000	2	506	Link16	Ocean	J2.00002	Link16	-117.672	6720	6720	)0001J2.00	1	FALSE
5	J1.00001	2	3	51:18.1	s36:05:13	e137:54:09	2000	2	506	Link16	Ocean	J2.00002	Link16	-117.672	6720	6720	)0001J2.00	1	FALSE
6	J1.00001	2	3	51:24.8	s36:04:18	e137:54:21	2000	2	506	Link16	Ocean	J2.00002	Link16	-106.261	6720	6720	)0001J2.00	1	FALSE
7	J1.00001	2	3	51:24.8	s36:04:18	e137:54:21	2000	2	506	Link16	Ocean	J2.00002	Link16	-106.261	6720	6720	)0001J2.00	1	FALSE
8	J1.00001	2	3	51:31.6	s36:03:22	e137:54:35	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.149	2000000	2000000	)0001J2.00	1	FALSE
9	J1.00001	2	3	51:31.6	s36:03:22	e137:54:35	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.149	2000000	2000000	)0001J2.00	1	FALSE
10	J1.00001	2	3	51:38.3	s36:02:28	e137:54:48	2000	2	506	Configured	Ocean	J2.00002	TTNT	-113.563	2000000	2000000	)0001J2.00	1	FALSE
11	J1.00001	2	3	51:38.3	s36:02:28	e137:54:48	2000	2	506	Configured	Ocean	J2.00002	TTNT	-113.563	2000000	2000000	)0001J2.00	1	FALSE
12	J1.00001	2	3	51:41.7	s36:01:59	e137:54:54	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.248	2000000	2000000	)0001J2.00	1	FALSE
13	J1.00001	2	3	51:41.7	s36:01:59	e137:54:54	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.248	2000000	2000000	)0001J2.00	1	FALSE
14	J1.00001	2	3	51:45.3	s36:01:30	e137:55:01	2000	2	506	Configured	Ocean	J2.00002	TTNT	-101.872	2000000	2000000	)0001J2.00	1	FALSE
15	J1.00001	2	3	51:45.3	s36:01:30	e137:55:01	2000	2	506	Configured	Ocean	J2.00002	TTNT	-101.872	2000000	2000000	)0001J2.00	1	FALSE
16	J1.00001	2	3	51:51.9	s36:00:36	e137:55:14	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.346	2000000	2000000	)0001J2.00	1	FALSE
17	J1.00001	2	3	51:51.9	s36:00:36	e137:55:14	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.346	2000000	2000000	)0001J2.00	1	FALSE
18	J1.00001	2	3	51:58.1	s35:59:46	e137:55:26	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.404	2000000	2000000	)0001J2.00	1	FALSE
19	J1.00001	2	3	51:58.1	s35:59:46	e137:55:26	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.404	2000000	2000000	)0001J2.00	1	FALSE
20	J1.00001	2	3	52:04.6	s35:58:53	e137:55:39	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.466	2000000	2000000	)0001J2.00	1	FALSE
21	J1.00001	2	3	52:04.6	s35:58:53	e137:55:39	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.466	2000000	2000000	)0001J2.00	1	FALSE
22	J1.00001	2	3	52:11.1	s35:57:59	e137:55:51	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.528	2000000	2000000	)0001J2.00	1	FALSE
23	J1.00001	2	3	52:11.1	s35:57:59	e137:55:51	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.528	2000000	2000000	)0001J2.00	1	FALSE
24	J1.00001	2	3	52:17.6	s35:57:06	e137:56:04	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.589	2000000	2000000	)0001J2.00	1	FALSE
25	J1.00001	2	3	52:17.6	s35:57:06	e137:56:04	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.589	2000000	2000000	)0001J2.00	1	FALSE
26	J1.00001	2	3	52:23.9	s35:56:15	e137:56:16	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.648	2000000	2000000	)0001J2.00	1	FALSE
27	J1.00001	2	3	52:23.9	s35:56:15	e137:56:16	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.648	2000000	2000000	)0001J2.00	1	FALSE
28	J1.00001	2	3	52:30.5	s35:55:21	e137:56:29	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.707	2000000	2000000	)0001J2.00	1	FALSE
29	J1.00001	2	3	52:30.5	s35:55:21	e137:56:29	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.707	2000000	2000000	)0001J2.00	1	FALSE
30	J1.00001	2	3	52:36.9	s35:54:29	e137:56:41	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.769	2000000	2000000	)0001J2.00	1	FALSE
31	J1.00001	2	3	52:36.9	s35:54:29	e137:56:41	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.769	2000000	2000000	)0001J2.00	1	FALSE
32	J1.00001	2	3	52:43.3	s35:53:36	e137:56:54	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.828	2000000	2000000	)0001J2.00	1	FALSE
33	J1.00001	2	3	52:43.3	s35:53:36	e137:56:54	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.828	2000000	2000000	)0001J2.00	1	FALSE
34	J1.00001	2	3	52:49.6	s35:52:45	e137:57:06	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.884	2000000	2000000	)0001J2.00	1	FALSE
35	J1.00001	2	3	52:49.6	s35:52:45	e137:57:06	2000	2	506	Configured	Ocean	J2.00002	TTNT	-119.884	2000000	2000000	)0001J2.00	1	FALSE
36	J1.00001	2	3	52:56.5	s35:51:48	e137:57:19	2000	2	506	Configured	Forest	J2.00002	TTNT	-109.122	2000000	2000000	)0001J2.00	1	FALSE
37	J1.00001	2	3	52:56.5	s35:51:48	e137:57:19	2000	2	506	Configured	Forest	J2.00002	TTNT	-109.122	2000000	2000000	)0001J2.00	1	FALSE
38	J1.00001	2	3	53:03.2	s35:50:54	e137:57:32	2000	2	506	Configured	Forest	J2.00002	TTNT	-105.675	2000000	2000000	)0001J2.00	1	FALSE
39	J1.00001	2	3	53:03.2	s35:50:54	e137:57:32	2000	2	506	Configured	Forest	J2.00002	TTNT	-105.675	2000000	2000000	)0001J2.00	1	FALSE
40	J1.00001	2	3	53:10.2	s35:49:56	e137:57:46	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-89.3043	2000000	2000000	)0001J2.00	1	FALSE
41	J1.00001	2	3	53:10.2	s35:49:56	e137:57:46	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-89.3043	2000000	2000000	)0001J2.00	1	FALSE
42	J1.00001	2	3	53:16.9	s35:49:01	e137:57:58	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-120.134	2000000	2000000	)0001J2.00	1	FALSE
43	J1.00001	2	3	53:16.9	s35:49:01	e137:57:58	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-120.134	2000000	2000000	)0001J2.00	1	FALSE
44	J1.00001	2	3	53:23.3	s35:48:09	e137:58:11	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-85.6112	2000000	2000000	)0001J2.00	1	FALSE
45	J1.00001	2	3	53:23.3	s35:48:09	e137:58:11	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-85.6112	2000000	2000000	)0001J2.00	1	FALSE
46	J1.00001	2	3	53:29.7	s35:47:17	e137:58:23	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-107.295	2000000	2000000	)0001J2.00	1	FALSE
47	J1.00001	2	3	53:29.7	s35:47:17	e137:58:23	2000	2	506	Configured	Agricultural	J2.00002	TTNT	-107.295	2000000	2000000	)0001J2.00	1	FALSE

Figure 6: Filtered data, showing connections between platforms J1.00001 and J2.00002 only

By analysing the data and graphs, the performance of different Tactical Data Link configurations can be investigated for a given scenario, and the performance benefit associated with effective ad-hoc networking can be seen graphically. In addition, using the same Tactical Data Link configuration for different scenarios allows the user to see the effect of terrain and land usage on specific data links.

4.6 Networking

As well as evaluating the relative performance of current and future Tactical Data Links, the QoS software will be used to investigate the effect modern networking techniques can have on both resulting data rate and overall connection quality. Networking (or relaying) is already used to allow for Beyond Line-Of-Sight (BLOS) connections from LOS links, such as Link-16.

Within the QoS software, Dijkstra's algorithm is used for shortest-path routing, that is; to determine the best route from one node to another, and the resulting data transfer rate. This is a dynamic process, with routes changing within the software as range, terrain effects and jamming cause point-to-point links between nodes to either decrease in transfer rate or be prevented entirely.

Current TDLs (ie L-16) generally require all network participants to be predefined before use, and do not have the capability to dynamically change them ad-hoc. Many future TDLs (ie TTNT, WNW) will have this capability, and in most cases it is automatic. Through the use of future Gateways in a future Global Information Grid environment the QoS software (in a replay mode) can show the most efficient route selected between nodes or network configurations using the selected current and future TDLs in the scenario selected.

An example of the impact that efficient networking can have on resulting connection quality can be seen in Figure 7. This graph shows the connection between two gradually separating platforms over time, with the blue trendline denoting a purely point-to-point link, with no networking allowed, and the red trendline denoting the connection when shortest-path routing is enabled, allowing the connection to pass through other nearby platforms when a point-to-point link is not available (due to terrain, jamming, range, or lack of LOS). As can be seen, networking and efficient routing between platforms allows for a far greater average connection transfer rate.

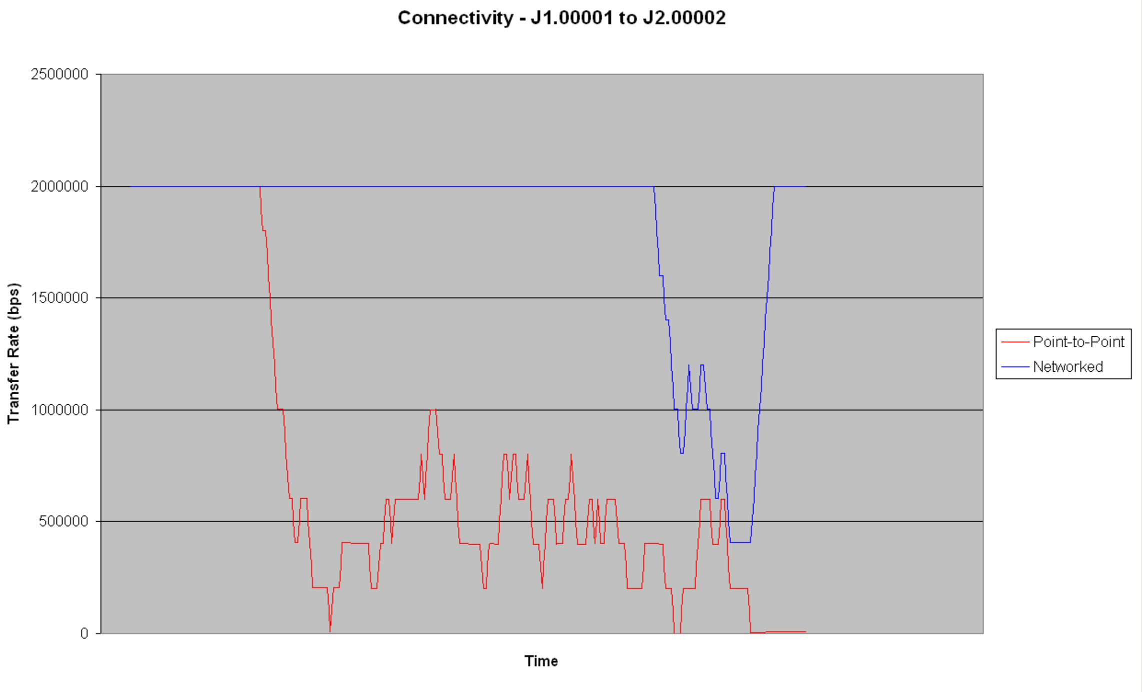


Figure 7: A comparison of a connection using networking, with a connection only allowing point-to-point communication

The amount of times a transmission must be relayed through other platforms is known as the 'hop count'. For a purely point-to-point connection this number will always be one, unless no connection exists at all. Figure 8 shows a summary of the number of hops between the two platforms during the scenario, as a proportion of the total number of time units.

It can be seen that the use of efficient networking between platforms can allow for a large increase in transmission quality and range, as a connection can be made between two platforms which would not be able to communicate using a purely point-to-point link. There are some caveats to this advantage, however. A transmission requiring multiple hops suffer from a greater latency than one performed with a single hop, as each platform involved in routing the transmission must collect and relay the information, with a corresponding lag introduced each time.

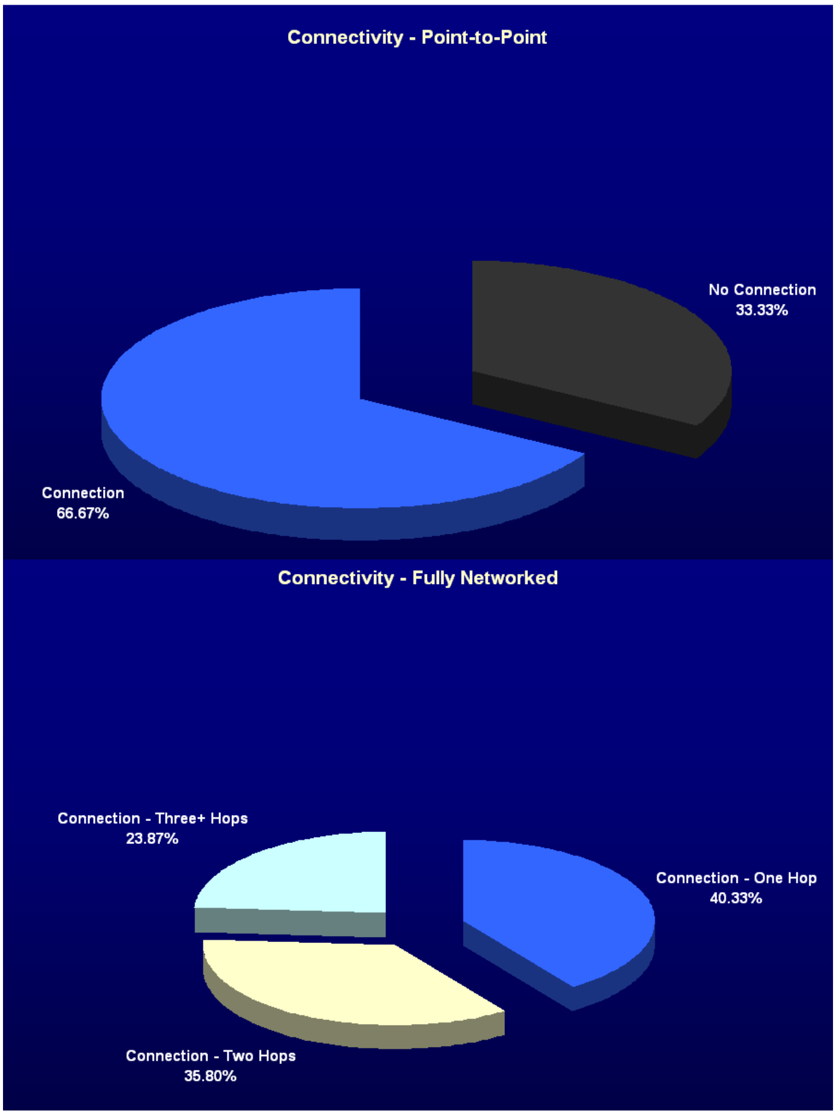


Figure 8: Hop count for networked and point-to-point connection types, for connections between J1.00001 and J2.00002

In addition, an upper limit exists on the amount of hops possible for a transmission (the exact limit depending on the specific TDL being used), and a platform performing relaying of a transmission cannot perform any transmission or reception of it's own until relaying is complete. Therefore, despite the great advantages provided by the use of networking, care must be taken to ensure that the regular transmission requirements of a platform are not impaired by the need to act as a relay for other platforms – particularly when using Time Division Multiple Access (TDMA) based links such as Link-16 and Link-22.

5. Summary and Conclusion

In summary the QoS software tool will be integrated into the ASCEL (using Rosetta) and hence realistically characterise the radio communication environment in the tactical battlespace. The software tool will display the quality of service between any platform or testbed / node, and add more realism in a Net Warrior exercise by modelling connection between various nodes with realistic link propagation characteristics due to geographic, atmospheric and other signal to noise ratio effects. The software tool will also allow the analyst to replace existing Tactical Information Exchanges (TIEs) between nodes with various future TIEs as mentioned above and compare the effects. Several of these future TIEs are currently being developed and tested and may eventually be used in several of the new ADF platforms (i.e., Airborne Early Warning & Control aircraft, Joint Stike Fighter and the Air Warfare Destroyer).

The use of the COTS software ArcGIS allows for different maps to be loaded into the QoS Sofware, and also leaves room for future expansions in the capability of the simulation software, possibly through use of additional layers other than elevation and land usage.

For the scenario described in section 4 of this report the QoS software (in a replay mode) has given us an insight in a possible future environment to show the most efficient route selected between nodes or network configurations using selected current and future TDLs in a future Global Information Grid environment.

Finally as part of a vacational student project, several improvements have been made to the QoS software through coordination with CDCIN, and the creation of Visual Basic macros for performing common data analysis tasks. This has greatly assisted the interpretation of data produced by the QoS software. Derived from a possible future scenario using current and future data links an example of this has been displayed in Figures 7 and 8. These figures graphically display a comparison of the data transfer rates over time and hop counts between a point to point and networked connection between two nodes (J1.00001 and J2.00002).

6. References

[1] A. Filippidis, T. Doan, B. Tobin, “Net Warrior- DSTO Battlelab Interoperability”(2007), Brisbane, SimTecT 07 Simulation Conference, June 2007.

[2] “Airborne Network Architecture, System Communication Description & Technical Architecture Profile”, Version 1.1, (2004), USAF Airborne Network Special Interest Group, Electronic Systems Centre, 45 Arnold St., Hanscom Air Force Base, MA 01731-2142, www.herbb.hanscom.af.mil/Hot_Buttons/Airborne_Networking/AN_Architecture_7_Oct_2004.doc

[3] Zalcman, L., Blacklock, J., Filippidis, A., Lawrie, G., (2006) “The DSTO Net-Warrior Exercise- The ADGESIM Contribution”, SimTecT, Melbourne, 29 May, pp. 339-344.

[4] McHale, J., (2004), “Software-defined radio and JTRS”, Military and Aerospace Electronics, December, 2004.

[5] Australian Defence Force (2004), “Policy for Tactical Information Exchange to Support Network Centric Warfare”, December 2004, Version 5 (Tactical Information Exchange Integration Office, Canberra, Fyshwick).

[6] SPAWAR website, “What is a waveform”, http://enterprise.spawar.navy.mil/body.cfm

[7] North R., Browne N. & Schiavone L. (2006) “Joint Tactical Radio System-Connecting the GIG to the Tactical Edge”, Military Communication Conference, Washington DC, 23-25 Oct.

[8] Rockwell Collins, Inc., (2004), “TTNT communicating at the speed of battle”, 147-0180-006 –GS BUS 8/04 Copyright 2004,

[9] Goodman G.W., Washington JR. (2006) “Machine-to-machine”, Defense Technology International, September/October, pp. 40-44.

[10] (2002) “Common Data Link Waveform Specification, Specification 7681990”, Revision F, November 2002, p.1.

[11] Lucas C., (2005), “US Army Common Data Link Update”, International Datalink Symposium, 4-6 October 2005.

[12] Boyd J., Burgdorf S., (2005), “Common Data Link: Design issues, Performance, Applications, Trend and the future”, International Datalink Symposium, 4-6 October 2005.

[13] Synthesis (2005), “An Introduction to Link-22”, www.synthesysaustraliasia.com.

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION **DOCUMENT CONTROL DATA**	1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE	3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)
Investigating the Quality of Service of Current and Future Tactical Information Exchanges - Net Warrior	Document (U) Title (U) Abstract (U)

4. AUTHOR(S)	5. CORPORATE AUTHOR
Arthur Filippidis, Mark Eldridge, Maurizio Gencarelli	DSTO Defence Science and Technology Organisation 506 Lorimer St Fishermans Bend Victoria 3207 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TR-2429	AR-014-793	Technical Report	May 2010

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
2009/1076651	CIO 07/042	CIO (DICTCM)	16	13

13. URL on the World Wide Web	14. RELEASE AUTHORITY
http://www.dsto.defence.gov.au/corporate/reports/DSTO-TR-2429.pdf	Chief, Air Operations Division

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE, PO BOX 1500, EDINBURGH, SA 5111

16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CITATION IN OTHER DOCUMENTS Yes

18. DSTO RESEARCH LIBRARY THESAURUS http://web-vic.dsto.defence.gov.au/workareas/library/resources/dsto_thesaurus.shtml

Quality of Service, Tactical Information Exchanges

19. ABSTRACT

A series of Net Warrior exercises is planned to build, demonstrate and enhance Australian Defence Force Network Centric Warfare (NCW) interoperability. Under the auspices of Task CIO 07/042 and as part of a student vactional work experience project this report describes the use and functionality of the Quality of Service (QoS) software tool developed by Adelaide University under a DSTO contract funded by the AEW&C Project. It realistically characterises the radio communication environment in the tactical battlespace, and with the use of a Rosetta Gateway can be used in future Net Warrior exercises involving Tactical Digital Information Links (TADIL) between nodes (ie. mission system test-beds) within DSTO. Using Rosetta together with the QoS software the report also analizes a possible future scenario using current and future data links comparing the tranfer rates over time and hop counts between point to point and networked connections between two nodes. In this case the report shows an improvement in the quality of service and reliability in a possible future Global Information Grid Environment where nodes are ideally networked.